REVIEW OF LITERATURE
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Loss of opposition of the thumb is a severe impairment to function of the hand. Usually it represents only a part of problems in peripheral paralysis of the upper extremity. As Kessler (1969) has pointed out combined median and ulnar palsy requires much more than opponens function to restore the muscle balance of the hand. The importance of restoring opposition is attested to by the many articles in the literature on this problem.

Definition of opposition

The term opposite implies, being set in position apart from another object. In astronomy planets 180° apart in their orbit are said to be in opposition. Thus touching the thumb to finger is not opposition but if thumb is brought forward and its pulp turned toward a finger, it is said to be opposed.
Napier (1966) defines opposition as a movement of the thumb as a whole which results in the pulp surface being placed squarely in contact with or diametrically opposite to the pulp surface of one or all of remaining digits. It is apparent from this definition that not only is the thumb involved in the functional concept of opposition but digits also.

Bunnell (1938) emphasized that the thumb in true opposition must not only be opposite to the fingers and forward from them, but it must also be by rotation diametrically opposite to them, with the pulp of the thumb facing that of the fingers and with the thumb nail parallel to the palm or volar surface of the digits.

Napier's (1966) studies in evolution, show that opposite digits are not limited to manus alone through out the tetrapode the pollex and hallux evince a tendency to diverge from other digits. It is beleived that some early mammals were orboreal and could use the hand as primates do with a grasp between proxial and remaining digits. Among the primates this grasping ability is developed in both hand and foot. Although it is absent from the human
foot and not always effective in the primate hand. In Gibbons, for example, the hand is used as a hook in branchiating or swinging from branch to branch and thumb does not effectively oppose to other digits, the foot in contrast has an excellent grasp. In most primates the distal end of 1st metatarsal is not tied by ligaments to the second, which allows the hallux marked freedom of movement. In mankind however the first and second metatarsal are so connected, all five being connected by ligaments. The human thumb, on the contrary is even better developed for opposition than in other primates. Those with the most opposable thumbs are in order. Man, gorilla, babbon, chimpanzee, and orangutan.

The thumb which has lost the power of opposition has been called "Ape thumb". This according to Bunnell (1938) is an injustice to the apes as in their hand opposition is well developed and it is even were so in their great toes.

Functional Anatomy of thumb and Mechanism of opposition

Movements of thumb involved in opposition are highly complex and have been analysed by many investigators. Historically the signifance of the
opposition of the thumb and its anatomical and functional basis were firmly established in 1867 through the accurate observations and deductions of Duchenne in his work "The physiology of motion".

At the start the thumb and thenar eminence form a cone which protruding latrally from the hand. Then thumb is extended and abducted. When midway in the part of arc the cone projects forward from the hand and thenar creases are folded to right angle to the plain of palm and the bones are in straight line as seen from behind. These relationship an maintained as the thumb is lifted away from the hand and brought forward but as the first third of motion is completed, the nail starts to rotate in pronation and the proximal phalanx angulate radially on the metacarpal. As this occurs, the muscles of the radial half of thenar eminence conspicuously spring to into action and continues motion. Throughout the arc the long extensors maintain the necessary stabilization in extension of the joint of thumb. Until the thenars have exhausted their amplitude, then the long flexor bind the distal joint and nail pronated further.
The motion of opposition takes place in the carpometacarpal and metacarpo-phalangeal joints. This motion is of two types angulatory and rotatory. At the carpometacarpal joint abduction, flexion and medial rotation. While flexion and pronation at proximal phalanx with radial deviation.

The joints involved in the their movements have a range of freedom which increases from the distal to proximal. The interphalangeal joint is of trocheal type and is only capable of flexion and extension. The metacarpophalangeal joint is condyloid, permits in addition lateral movement and axial rotation. Finally the trapeziometacarpal joint with its saddle shaped articular surfaces allow the wide range of movements of the first metacarpal mentioned above in addition to movement of circumduction.

**Carpometacarpal joint of the thumb**

Carpometacarpal joint of thumb is saddle joint and functional advantage of this joint is that it achieves the mobility of ball and socket joint without sacrificing stability and without need for large articular surfaces (Napier, 1966). The joint is surrounded by fibrous capsule loose but thick and
passes from the circumference of the base of first metacarpal to the rough edge binding the articular surface of the trapezium. The capsule is thickest laterally and dorsally. The synovial membrane which lies the fibrous capsule is distinct from that of the other carpometacarpal joint.

In addition to the capsule, the first metacarpal is connected to the trapezium by lateral, anterior and posterior ligaments. The lateral ligament is relatively broad band running from the lateral surface of the trapezium to the radial side of the base of first metacarpal bone. The palmar and dorsal ligaments are oblique bands which converge to the ulnar side of the base of the metacarpal bone from the palmar and dorsal surface respectively of the trapezium. These two ligaments play an important part in connection with the movements of the thumb.

The active movements that are possible in the joint are flexion, extension, abduction, adduction, rotation and circumduction. For a description of the movements of the thumb, ventral position of the thumb metacarpal which corresponds to the position of rest of thumb is taken as starting point. The trapezium is set in the carpus in such manner that the long axis of the articular surface makes an angle of
approximately 80° with the plane of the palm. Owing to the corresponding set of the first metacarpal bone in position of rest, flexion and extension takes place in plane parallel to the palm while abduction and adduction occur in a plane at right angle to flexion extension.

Except in its early stage flexion of the first metacarpal bone which takes place in the plane of the concavity of the trapezium is always associated with medial rotation and conversely medial rotation can not be performed actively apart from flexion (Napier, 1960). Similar full extension of the first metacarpal is associated with a slight amount of lateral rotation. This has been attributed to the fact that the ulnar side of base of metacarpal becomes anchored by the tension of the palmar ligament while the radial side is still free to move and continued action of the extension of the thumb produces lateral rotation in addition to further extension.

The motion of opposition takes place in the carpometacarpal and metacarpophalangeal joint. This motion is of two types angulatory and rotatory. The carpometacarpal joint furnishes most of the angulatory movement and the metacarpophalangeal joint most of
the pronatory movement. The angular movement takes place in plane of concavity of trapizium, as a result the first metacarpal moves away from the second metacarpal in somewhat in anterodorsal direction in an arc of about 120°. Movement in ulnar direction is associated with pronation of the metacarpal and movement in radial direction with supination. According to Napier (1966) pronation or medial rotation of the metacarpal is the inevitable accompaniment of abduction followed by circumduction in ulnar direction.

When the thumb opposes there is no perceptible change in the position of scaphoid and only a questionable shift in the trapezium provided that the wrist is held immobile.

The position of rest of the hand is one in which the palm of the hand is hollowed, the fingers are flexed and thumb slightly opposed, the wrist is abducted so that when the elbow is extended the axis of middle finger parallel to that of humers and not to that of the bone of forearm.

In 1956, Napier defined power grip and precision grip as the basic restive grips in loaded hand activities. He defined grip as forcible activities
of the fingers and thumb against the palm, for the purpose of transmitting force to an object. Precision grip was manipulation of an object between the thumb and the finger tips, not against the palm. Lansmeer (1962) added to the concept of precision grip the observation that was primarily a manipulative rather than gripping activity and should be called "Precision handling".

Articular surfaces of trapeziometacarpal joint provides two positions of function in which the articular surfaces are congruent, viz. adduction and abduction and a position of rest which is intermediate between abduction and adduction in which the articular surfaces are uncongruent and joint freely mobile. Thus stability of thumb may be achieved either in full adduction, extension and lateral rotation or in full abduction, flexion and medial rotation these two position form the basis of power and precision grip.

Power grip comes into action when force is required as in manipulating tools, climbing and so on. The long flexor muscles in association with the extensors of wrist, contract to group a power grip, in which the fingers are brought towards the palm round the object gripped and the thumb is flexed
at carpometacarpal joint and extended at interphalangeal joint.

Precision grip is used to handle an object which is siezed with the pads of fingers which spread around it. This entails a considerable amount of rotation some active, some passive at the metacarpophalangeal joint. This rotation is sufficient to being the pad of index finger at right angle to the pad of little finger, other fingers occupying an intermediate position. The thumb lies in position of opponens.

The thumb plays an important role in both grips. The two types of grips are largely independent of each other and can be seperately abolished (Napier, 1956; Bowden and Napier, 1961).

Another type of grip is hook grip (Napier, 1956) closely resembles, the power grip but thumb plays little or no part. It is used for carrying suit case and in rock climbing.

**Muscles of the thumb**

The muscles which take part in the movement of opposition are thenar muscles and the long muscles of the thumb. The thenar muscles may be considered under two headings lateral and medial.
The lateral thenar muscle are abductor pollicis brevis, flexor pollicis brevis and the opponens pollicis.

Nerve supply of these three muscles is by median nerve and they are inserted into the radial side of proximal phalanx of thumb. With the exception of opponens pollicis which inserts entirely into the palmar surface and radial border of first metacarpal. The muscle as a group brings the palmar surface of the top of the thumb parallel to the palmar surface of the fingers and then brings the surfaces of thumb and fingers into contact i.e. the action of opposition.

Medial thenar group comprises adductor pollicis and first palmar interosseus and are supplied by ulnar nerve. They are inserted to the ulnar side of base of proximal phalanx of thumb and flex the metacarpophalangeal joint. in addition to supination and adduction of thumb toward second metacarpal.

Rowntree (1949) found that in about twenty percent of cases there are some variation on nerve supply of the thenar muscles. In over ninety percent of cases the abductor pollicis brevis and adductor muscles were supplied by median and ulnar nerve respectively. The opponens pollicis usually supplied
by median nerve. But the innervation of flexor pollicis brevis was more variable. In over half of his cases, the flexor brevis had a dual nerve supply. When the ulnar nerve supplies both the heads of flexor brevis opposition is possible even in the absence of opponens action. Of the 25 cases, section of median nerve below the elbow studied by Tubiana and Valentin (1968), a significant degree of opposition was present in eight cases prior to surgical repair. They pointed out that if the median nerve is served above the elbow an even greater number of abnormal innervations are discovered, probably because of exchange of nerve fibres which takes place between the median and ulnar nerves in the forearm at the so called anastomosis of the Martin-gruber. Thus Boswick (1967) found a complete loss of opposition in only 5 of 13 section of the median nerve above the elbow.

As White has suggested the thenar muscles are attached to the thumb in the shape of a fan. The wide range of movements of the thumb is obviously the result of successive contraction of the various bundles within this mass of muscle. The movement of opposition begins by contraction of the muscles at
the radial border of the mass and when the surface of the thumb meets the surface of one of the finger tips, power is added to the pinch by contraction at the ulnar border of the mass.

The extrinsic muscles of the thumb viz. the extensor pollicis longus, the extensor pollicis brevis, the abductor pollicis longus and the flexor pollicis longus assist and guide the movements of the thumb. The flexor pollicis longus which flexes the phalanges also reinforce adduction in the course of pinching. The abductor pollicis longus initiates the movement of abduction at carpometacarpal joint by assisting the abductor brevis but relaxes as soon as the thumb is fully flexed and pronated, acting with the extensor pollicis brevis, it opens up the "pollici-digital pincers" as essential pre-requisite to opposition (Tubiana and Valentin, 1968).

The extensor expansion of the thumb

In elucidating the mechanisms of the thumb motion, Duchenne (1867) credit to Sabalier who noted the union between many fibers of the thenar eminence and the tendon of the long extensor of the thumb". He then described the terminal tendinous insertion of the abductor pollicis brevis in the following manner.
"Its tendon passes to the radial side of the proximal phalanx and is thus inserted partially. Some of the fibers are inserted into tendon of extensor of the thumb and are continued toward its end". Albinus (1734) in his Historia Muscularum Hominis also described this projection of the short abductor febers into the extensor tendon.

Extensor complex of the thumb is similar in most respect to that of finger is now well accepted. The extensor pollicis longus tendon forms the central portion of an expansion, which receives tendinous febers from the radial and ulnar side and from the tendon of extensor pollicis brevis. The tendons of abductor pollicis brevis and flexor pollicis brevis blends with the capsule of the metacarpophalangeal joint and insert into the radial side of the base of proximal phalanx. In addition tendinous febers proceed as a lateral band to contribute to the extensor expansion. Similarly tendons of the transverse and oblique heads of the adductor pollicis proceed to the ulnar side of the base of the proximal phalanx and blend with the joint as well as inserting into the proximal phalanx. The tendinous fibers proceed beyond their attachment to bone to contribute the ulnar side of the extensor
expansion by virtue of their insertion into the extensor expansion of the thumb, these muscles also extend the distal joint of the thumb.

The thenar muscles are intimately associated anatomically and their actions are complementary and directed toward positioning the thumb for pinch and grasp. The faradic and anatomical studies of Duchenne led him to define the functional importance of abductor pollicis brevis. He noted that the short abductor of the thumb produced a movement similar to the action of opponens pollicis and that it also extended the distal phalanx, inclined the proximal phalanx radially and caused medial rotation of the thumb about its long axis this combination of movements brings the thumb opposite the fingers for effective pinch between their volar tactile surfaces. In Duchenne opinion, opposition resulted from the combined actions, the abductor pollicis brevis supplying most of the power to the flexor pollicis brevis and the opponens pollicis brevis. He also emphasised the importance of the flexor brevis, not only this can execute the same movement as of abductor pollicis brevis. It is the only muscle that produce enough abduction at the metacarpophalangeal joint to approximate the ulnar two fingers.
Kaplan (1953) affirmed Duchenne's conclusion and elaborated that in simple effortless opposition, the muscle involved are opponens pollicis, abductor pollicis brevis and flexor pollicis brevis with assistance from the abductor pollicis longus and extensor pollicis brevis. If force is added to this movement extensor pollicis longus and adductor pollicis also come into play.

Littler (1949, 1963) accords the abductor pollicis brevis prime importance amongst the thenar muscles because it stabilises the metacarpophalangeal joint in abduction and flexion as well as pronating the thumb and tending the distal joint. He is also agreed with the Duchenne regarding the importance of flexor pollicis brevis. He points out that in approximately 40 percent cases ulnar nerve supplies the lateral head of flexor pollicis brevis, so in median nerve paralysis opposition of thumb may not be greatly impaired "for alone the lateral head of flexor pollicis brevis serves to move the thumb as the resultant of forces of palmar abduction and adduction. The motion and flexion produced at metacarpophalangeal joint together with the abductor power make possible a fairly effective pinch between thumb and fingers".
Bunnell (1938) described opposition as a combination of rotation and angulation occurring at radioscapoid, intercarpal, carpometacarpal and metacarpophalangeal joints of the thumb. According to him, the first metacarpal is angulated and pronated at the basal joint of the thumb, largely by opponens pollicis aided somewhat by the abductor pollicis longus and by the outer head of flexor pollicis brevis. The proximal phalanx is angulated and pronated mostly by the lateral head of flexor pollicis brevis. The extensor pollicis longus stabilises the joints of thumb in extension alongwith the extensor pollicis brevis and abductor pollicis longus and then helps in opposition even being the most antagonist to opposition.

Steindler (1930) define opposition in very simple manner as first extension by two extensors, then abduction by two abductors and finally pronation by opponens and flexor pollicis brevis.

According to Grant (1958) during opposition - circumduction by abductor pollicis brevis aided by adductor, rotation by opponens pollicis and flexor pollicies brevis while flexion by flexor pollicis longus and brevis. He gave the term "pronator pollicis" which means that the superficial head of flexor pollicies brevis and opponens pollicis acts in a single functional unit.
Wynn Parry (1966) gives main importance to abductor pollicis brevis in opposition, it opposes the thumb to index and middle finger while the superficial head of flexor pollicis brevis opposes the thumb to ring and little finger in continuation of this rotation and flexion at trapeziometacarpal joint is done by opponens pollicis. In two cases in whom the ulnar nerve supplied the opponens and the median nerve supplies the abductor pollicis and superficial head of short flexor, Wynn Parry demonstrated that the stimulation of median nerve above the elbow produced significantly more opposition than the stimulation of the ulnar nerve.

Mc Farlane (1962) gave little importance to opponens pollicis in movement of opposition. Because the opponens pollicis acts only upon the first metacarpal. He considers the abductor brevis and flexor brevis as the important muscles in full opposition and circumduction of the thumb. According to him functional unit comprise the abductor pollicis brevis and first palmar interosseous. He is with littler regarding the importance of transverse head of adductor to add power to the action of pinch and grasp.
Electromyographic studies were done by Forrest and Basmajian (1965) to determine the function of thenar and hypothenar group of muscle in twenty five normal subjects externally five indwelling electrodes were used. They found that not all thenar muscles were active in all thumb positions. Increasing activity occurred in the thenar muscles as the thumb was held softly opposed to each of fingers beginning with the index and advancing in steps to long, ring and little fingers. The same pattern was true for hypothenar muscles beginning with opposition to the ring finger. The thenar muscle always showed more activity than the hypothenar muscles and each opponens muscle was dominant in its own group when the thumb opposes firmly to the middle and index finger's flexor pollicis brevis replaced the opponens as the most active of the six muscles. The opponens pollicis I however, approached and then equalled the flexor in its activity during firm opposition to the ring and little fingers.

**Causes of loss of opposition**

Loss of opposition may be due to paralysis of the muscles of the radial half of thenar eminence as may occur in leprosy, poliomyelitis and median
nerve trauma. According to Selvapandian and Brand (1958) the commonest cause of paralytic hand in world today is leprosy. Opposition function may be lost in severe trauma to thenar group of muscles. Injuries to the joints involved in opposition movement, ankylosis of the intercarpal and carpo metacarpal joints, cicatrical contracture from infection which approximates the first two metacarpals, adhesions which hold back the tendon of extensor pollicis longus and flat hand from faulty splinting, occasional causes. Bunnell (1956) claims protrusion of disc between the sixth and seventh cervical vertebra selectively result in loss of opposition. Carpal tunnel syndrome and local channel contracture of the adductor muscles may also produce the functional loss.

Restoration of opposition

Opposition may be restored depending on its cause by nerve suture by excision of cicatrix binding the first and second metacarpal or by wedge osteotomy in case of ankylosis of carpus. Bunnell (1938) reports sixty six percent success in restoring opposition in a series of eighty three repairs of median nerve by suture.
When the damage to nerve and muscles are beyond repair some form of tendon transfer will be required to restore. Opposition various motors and routes of transfer have been used. Some methods require lengthening of the motor tendon by a free graft and others require construction of pulley mechanism.

In 1938, Sterling Bunnell postulated the two "essential principles" of opponensplasty. He stated that any adequate motor could produce opposition provided the surgical procedure adhere to two basic principles viz:

1- "The tendon from its insertion in the thumb should pass subcutaneously in the direction of pisiform bone so that it will pull the thumb in the correct direction" and

2- "The insertion of the tendon should be on the dorsoulnar aspect of the base of the proximal phalanx of the thumb, so as to restore the pronatory component.

Bunnell recommended either a wrist flexor or a ring finger flexor as the motor and construction of pisiform pulley to provide the correct direction of pull. The first case in which he used these principles
was reported in 1924. Since then transfer of the flexor digiterm sublimes of the ring or long finger became the preferred method for restoration of opposition even though many other method have been subsequently evolved.

In 1958, Selvapandian and Brand, based on their experiences in restoring opposition in leprosy hands stated that a tendon transfer for paralysed thumb should accomplish three things:

1- Abduction of the thumb at carpometacarpal joint.
2- Abduction of the proximal phalanx at the metacarpophalangeal joint.
3- Extension of the interphalangeal joint.

They used one of the tendons of the flexor digitorum sublimes for this purpose.

According to Tubiana (1969) the nearest one can get to achieve restoration of opposition is to use a transfer which:

1- "In cases of paralysis of lateral thenar muscle will act in the axis of abductor pollicis brevis.

2- In cases of paralysis of the medial thenar muscle will pull in the direction of the adductor and
3- In cases of paralysis of both groups will provide the actions of both of the previous transfers or if only a single transfer is possible will pull in the direction of the flexor pollicis brevis.

Correction of fixed deformities

To restore function of their correctly, deformities or disabilities of digits other than those corrected by the operation, designed primarily to restore opposition must be corrected prior to or at the time of tendon transfer.

A fixed adduction and external rotation deformity of the thumb is not uncommon. Specially in long standing cases. This may be corrected by dividing the fascia in the web space between the thumb and index metacarpals and by subperiostial stripping of ulnar side of first metacarpal as recommended by Goldner and Irwin (1950). Z-plasty as recommended by Brand (1964) may be done in severe cases. Rotation osteotomy of first metacarpal may be done when it is of no use then arthrodesis of trapeziometacarpal joint may be indicated (Millford, 1963). But when mobility is more desirable than stability Millford recommends excision of trapezium which may release soft tissue enough to make arthrodesis unnecessary.
Interphalangeal joints may require fusion occasionally for a severe fixed flexion deformity which cannot be corrected by prolonged physiotherapy.

Selection of motor

The proper muscle for a motor is selected after carefully evaluating the strength of muscle in the rest of hand. The flexor digitorum sublimis of the ring finger is usually the muscle of choice and is often used when it is strong enough to function as the motor and when its associated flexor digitorum sublimis is strong enough to flex the finger satisfactorily, second choice is sublimis to middle finger. The standard techniques of Bunnell, T.C. Thompson and Brand utilise either of these two tendons.

Various other procedures have also been done for opponensplasty.

Steindler was the first to report on an operation to restore opposition of thumb at 69th Annual Session of the American Medical Association in June 1918. He split the distal end of flexor pollicis longus tendon longitudinally into two halves. The radial half of the tendon was severed at the distal end and the tendon was carried around through a tunnel in to the soft tissue to the base of the proximal phalanx.
Kukenberg split long finger sublimis tendon from the middle phalanx to the transverse carpal ligament and passed around a notch in transverse carpal ligament and sutured to the periosteum of the first metacarpal.

Ney (1921) devised a procedure for retaning the thumb in normal position when complete intrinsic paralysis was present. He detached the extensor pollicis brevis tendon at its musculo-tendinous junction and after passing it under the flexor retinaculum sutured it to the tendon of palmaris longus or of the flexor carpi radialis proximal to transverse carpal ligament. Phalen and Miller (1947) and Kessler (1969) used extensor carpi ulnaris as the motor and passing it around the distal end of ulna subcutaneously anastomose it to the extensor pollicis brevis tendon.

In 1921 Huber and Nicolaysen independently transferred the abductor digiti minimi on its neurovascular bundle and attached it to the first metacarpal.

In 1963 Litter and Cooley renewed interest in this procedure and emphasized the technical aspect of preserving the neurovascular bundle to the abductor digiti minimi.
Silfverskiold (1928) detached the flexor pollicis longus tendon rerouted it around the radial side of the thumb and inserted it at the base of proximal phalanx.

In 1930, Von Baeyer described the method of "Translocating" the flexor pollicis longus tendon through a circular incision around the thumb, the tendon was freed. It was then looped over the tip of the thumb and wound around the proximal phalanx to oppose the thumb. Myser Makin (1967) modified the technique by translocating the tendon through an oblique osteotomy of the proximal phalanx of the thumb. He recommends this procedure in those cases where no other tendon is available for transfer.

Although Bunnell's classical operation on opponensplasty was not published until 1938. He was writing about the subject as early as 1924.

Howell (1926) used flexor pollicis brevis.

John (1929) transferred the extensor digiti communis tendon.

Royle (1938) passed the ring sublimis up the sheath of flexor pollicis longus and inserted it into the outer edge of the opponens pollicis and flexor pollicis brevis muscle.
Handerson (1962) reported on his experiences using any available wrist extensor or brachio radialis to restore thumb opposition. The muscles were elongated with either a free graft or distally attached extensor pollicis brevis tendon.

Zancoli (1965) transferred the extensor indicis proprius tendon around the ulnar border of wrist.

Extensor digiti minimi was originally used by Dr. Robert Cook during the first world war in a patient who had been shot through the first web space. R.J. Taylor described the cooks procedure in detail. Recently interest was revive in this technique by the work of Schneider (1969) who reported a series of ten cases in which this operation was done. Of these seven were cases of combined median and ulnar nerve.

Nerve injury, two patients had brachial pluxes injuries with return of protective sensation but no available flexor motor for transfer one patient had residual poliomyelitis. Schucider clarified his results as eight 'good' and two 'fair'.

Construction of pulley

Bunnell (1938) states that construction of pulley at or adjacent to the pisiform bone is required to produce true opposition. He used the
flexor carpi ulnaris for this purpose either by making a loop at the distal end of tendon or by passing the motor around this tendon. If the muscle is not paralysed. Radial migration of this type of pulley has been observed with subsequent weakening in the power of opposition.

Jacob and Thompson (1960) stated that to reproduce true opposition it is desirable to construct a pulley which has the following properties:

1. It should be securely fixed.
2. It should be in such a position that the motor tendon approached its insertion at as near a right angle to the long axis of thumb is possible, since the magnitude of the force exerted at the point of tendon insertion varies directly with the angle of insertion upto 90 degree.
3. It should be at sufficient distance from the thumb to permit enough excursion of the transplanted tendon to produce an adequate range of opposition.

The thompson pulley utilizes the junction of the distal margin of the flexor retinaculum with the ulnar border of the palmar apponenrosis.
Brand (1964) utilizes the "ulnar tunnel" just lateral to the pisiform as a pulley.

If an extensor tendon is used for opponensplasty as in the present study using extensor digiti minimi, the distal end of ulna will act as a pulley because the tendon has to be re-routed around the ulnar border of the forearm into the thumb.

Srinivasan (1969) has done away with the construction of pulley. Splitting the sublimis tendon as far proximally as possible well above the wrist. He passes one slip subcutaneous by along the lateral border of the first metacarpal to emerge at the lateral side of the base of the proximal phalanx, which he sutures to the tendon of abductor pollicis brevis. The other slip is passed subcutaneously through the palm to the medial side of the base of the proximal phalanx when it is sutured to the adductor tendon, the tunnel for this slip is made in such a way that it lies anterior to the basal and middle joints of the thumb.

Ranisellin (1970) emphasized the multitude of the pulley that have been used in opposition transfer and that the desired direction of pull of the transferred tendon can be altered by changing the location of pulley.
Insertion of Motor Tendons

It is generally accepted that for better result motor tendon should pass subcutaneously in the palm. But regarding the method of insertion of motor there is wide divergence of opinion.

According to pioneer in tendon transfer Bunnell (1936) the insertion of the tendon should be on dorsoulnar aspect of the base of proximal phalanx of the thumb, so as to restore the pronatory component of opponens, Bunnell clearly stressed that insertion should be pass directly over the summit of the metacarpophalangeal joint, not distal to it. Bunnell stated that if the insertion is made into the tendon of abductor pollicis brevis good pronation well be achieved. As the abductor pollicis brevis inserts into the aponeurotic hood of extensor expansion of thumb, it also helps to extend the distal joint of the thumb.

Bunnell also suggested an alternative way viz. using the tendon of extensor pollicis brevis which is inserted into the base of proximal phalanx of the thumb.

Ney (1921), phalen and muller 1947 and Kessler (1969) employed technique of Bunnell.
Kessler has demonstrated that when pulled in proper direction at an angle of not less than 50 degree to the long axis of the thumb, the tendon pronates, abducts and extends the thumb.

Royle (1938) passed the ring sublimis up the sheath flexor pollicis longus and inserted it into the outer edge of opponens pollicis and flexor pollicis brevis muscle respectively. T.C. Thompson modified Royle's technique, he attached one slip of sublimis tendon to neck of metacarpal and other to the base of proximal phalanx.

Riordan (1959) he sutured one slip of transferred tendon to the abductor pollicis brevis to provide opposition and abduction and other slip to the extensor pollicis longus to increase extension of distal joint of thumb. Brand (1964) attached one slip of sublimits tendon to the extensor pollicis longus and other to the tendon of adductor pollicis across the dorsal aspect of the metacarpal neck. Murley (1964) and Srinivasan (1969) sutured one slip of the tendon to the insertion of adductor pollicis and other slip to the insertion of abductor brevis. Unlike Brand's method, the slip meant for adductor pollicis does not cross over the dorsum of the thumb but passes directly along with medial side of the thumb to its insertion.
Makin in (1967) translocated the flexor pollicis longus to the radial side of the thumb through an osteotomy of proximal phalanx without detaching the tendon.

Lamb and Landry 1971, 1972 mentioned in hand in quadriplegia that by dividing extensor pollicis brevis at the musculotendinous junction and transposing it subcutaneously across to pisiform and suturing it to extensor carpi ulnaries gives thumb to pulp pinch in paralysis of thenar muscle.

**Stabilising the thumb index pinch**

The thumb can be made stronger for pinch either by an arthrodisis of its metacarpophalangeal joint or by a dynamic tendon transfer. Various tendon transfer have been suggested to provide index finger pinch. Brooks (1949) described the replacement of a weakened first dorsal interosscous, particularly to improve the stability of metacarpophalangeal joint of index finger during the action of pinch. It is possible to use the extensor indicis tendon which is passed anteriorly along the course of a weakened interosscous muscle at the lateral side of extensor expansion. Dynamic tendon transfers to substitute for adductor pollicis can be produced by passing the
tendon around the third metacarpal and the distal edge of the volar carpal ligament making the transfer approaches the thumb in the muscle plane of the adductor pollicis. One of tendons of flexor digitorum sublimis has been used for this purpose, Brachioradialis lengthened with free grafts has also been employed occasionally the flexor digitorum. Sublimis tendon has been split and the ulnar half split again into two slips. One for the extensor hood of the ring and other for the hood of little finger. The radial half then has been brought through the third metacarpal fascia and sutured to the tendon of adductor pollicis. Pinch of the index finger has been improved by splitting the tendon of extensor indicis, passing the radial half of tendon beneath the index extensor digitorum communis and suturing it on the radial side of the extensor hood. This gives stability and not active deviation of the finger. Zancoli (1957) prefers transferring the entire extensor indicis proprius into the interosseous tendon on the ulnar side of the index extensor hood. This gives some active opposition of the index finger to the thumb.

**Bone operations to restore opposition**

These operations restore only the position but not the movement of opposition and are done only
as a last resort when repair by nerve suture is not possible or in extensive paralysis of the limb with no available motor for transfer. Bunnell (1956) has described these bone operations for the purpose:

1- Osteotomy of the thumb metacarpal: - When the direction of thumb metacarpal is lateral and the carpometacarpal joint resists movement, Bunnell advises a rotatory angulatory osteotomy of the base of first metacarpal.

2- Carpal osteotomy: - In the case of fusion of carpus, a wedge osteotomy on the radial aspect has been recommended to restore the carpal arch and place the thumb in opposition.

3- Intermetacarpal fusion: - Foerster (1930) planted a 3 cm bone graft from the tibia between the first and second metacarpal in the position of opposition. According to Tubiana (1969) intermetacarpal fusion is more disabling than arthrodesis of the trapeziometacarpal joint and is only indicated as a last resort.
Tenodesis of the thumb

In the presence of active extension of the wrist a tenodesis which connects the thumb to the distal end of ulna, is preferred by some surgeons (Tubiana, 1969). Since this allows the thumb to come into opposition when the wrist is extended.

Assessment of the result

Despite the fact that numerous procedures have been described for restoring opposition of the thumb, there is a general paucity of information regarding the criteria of classification of the results.

Jacobs and Thompson (1960) classified their results as follows :-

'Good' or 'Excellent' results were those with at least seventy five percent of the function of the opposite thumb, when normal or those with less than 20 degrees of difference between the plane of the opposed thumb nail and the plane of the palm with good power. 'Fair' results were those with good rotation of the thumb and poor power or those with less rotation and good power. 'Poor' results (failures) included those with no thumb rotation and poor power.
Schneider (1969) evaluated the results according to the patient's ability to oppose the thumb i.e., to abduct the thumb forward of the plane of the palm and rotate the thumb nail into plane parallel to the plane of the little finger in tip-to-tip pinch. He graded the result 'good' if the thumb nail came to within 30 degrees of the palm, 'fair' if within 50 degrees and 'poor' if more than 50 degrees.

Srinivasan (1969) used a qualitative method of assessment based on the following criteria:

1- Posture of the resting thumb - whether the thumb at rest appeared normal or near normal, with no hyperextension at the middle joint.

2- Posture of the active thumb - whether the thumb appeared normal with no hyperflexion, during active abduction opposition.

3- Working of motor - whether the patient was using the motor tendon.

4- Extent of opposition - whether the thumb could be opposed to touch the tip of at least the ring finger.

5- Usefulness of the thumb after corrective surgery - whether the patient found corrective surgery had restored him a thumb useful for his activities.
6- Patient satisfaction - whether the patient was happy about the results of the procedure and would like to have the same procedure done on him again if the need arose; or whether he would recommend the same to be done for his friends having similar complaints.

If the answers to these questions were 'Yes' the result was considered satisfactory. If the answer is any of these question were in the negative the result was considered not satisfactory.